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Effects of Aeration and Temperature on
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Full-Scale Vessel System

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16. ABSTRACT Trials were replicated in an aerated reactor vessel to obtain quantitative data on the relationships between aeration, temperature, and performance of municipal sludge composting. Temperature, airflow, and carbon dioxide evolution were monitored continuously in sections (6.1 by 3 m deep) of the reactor. Aeration was regulated by temperature feedback to maintain sections of the reactor at widely different temperatures. Rates of drying and volatile solids destruction were considerably higher at mean temperatures of 40° to 60°C than at temperatures above 60°C. Carbon dioxide evolution rates comparable to those reported for laboratory composting trials indicated optimal microbial activity at mean temperatures between 40° and 60°C. High temperatures for pathogen destruction were achieved readily toward the end of the process by airflow reduction or reversal.			
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Effects of aeration and temperature on composting of municipal sludge in a full-scale vessel system

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Increasingly, composting is chosen as a treatment method for municipal sludges; more than 61 composting facilities operate in the U. S.¹ One of the principal objectives of composting, and the focus of much early research, has been to maintain the high temperatures (greater than 55°C) required for reduction of fecal pathogens. The aerated static pile system achieves these temperatures readily when operated with negative pressure aeration as in the Beltsville method.² Laboratory-scale composting studies have repeatedly demonstrated, however, that high temperatures (greater than 60°C) inhibit the activity of the compost microorganisms.³⁻⁶ Research has shown for the aerated static pile that when temperatures are maintained below 60°C with positive pressure aeration and temperature feedback control of fans, drying and decomposition rates are higher than those obtained in the Beltsville system, where process temperatures are not controlled.⁷ However, quantitative data on the relationships between aeration, temperature, and the rate of composting have not been published for replicated studies in a full-scale composting system. The objectives of this research were to determine the effects of aeration and compost temperature on activity of the compost microorganisms as measured by carbon dioxide evolution and losses of water and solids in replicated trials in a full-scale reactor system.

MATERIALS AND METHODS

Composting trials were performed in reactor vessels in a composting plant at Paygro, Inc., South Charleston, Ohio. This facility has been composting cow manure since 1971.⁸ Two tank reactors, each 121.9 m long, 6.1 m wide, and 2.9 m deep are positioned side-by-side. Air is forced by fans through an opening in a side wall into a plenum and up through a perforated metal floor. Centaxial vane fans (7.5 hp) are located at 12.1-m distances along the sidewalls; each supplies air to a separate, segmented portion of the plenum.

Six preliminary trials (from winter to summer, 1981) were performed to develop procedures for determining an accurate materials balance and for monitoring airflow, temperature, and carbon dioxide (CO₂) evolution. Four separate sections, each 6.1 m long by 6.1 m wide by 2.9 m deep (108 m³), were constructed with independent airflow systems, in which process temperatures were controlled accurately and concise materials balances were determined. Complete airflow control was achieved in the center two sections only and thus, quantitative data on airflow and CO₂ evolution were based only on

comparisons of treatments among separate experiments in those sections.

The highest composting rates were achieved when temperatures were kept below 60°C by high airflow rates.

Averaging Pitot tubes, installed in 40.6-cm (16-inch) in diameter by 7.3-m long (24-ft) ducts ahead of the intake end of each fan, were used to measure airflow into each section. Magnehelic differential pressure transducers, calibrated with an inclined manometer, provided a signal output which was interfaced with a data acquisition center. Hourly readings were recorded and compared twice daily with manual readings to verify the values.

Fans were generally controlled through feedback from thermocouples by a data logger/controller. This temperature control strategy for composting of municipal sludge was first used by Finstein at Rutgers University.⁶ The temperature control system was programmed to activate fans separately and maintain preset temperatures in each of the four sections of the reactor. At the onset of each trial, fans were operated by 10- or 30-minute timers, which could be set to provide 1-minute increments of aeration. Once the preset temperature point for a particular experiment was reached, the data logger/controller automatically controlled the fans. Each time fans were turned on and off, the event was recorded automatically. Thus, the number of minutes that each fan was in operation was determined accurately. Relative humidity of air entering the reactor was measured twice daily with a sling psychrometer (dry-wet bulb type). The amount of dry air that entered the reactor could, therefore, be determined. During most trials, fans were operated to provide positive pressure aeration. The static head pressure in the duct between the fan and the plenum was measured with a manometer twice daily. Effects of negative pressure aeration were also examined, but airflow rates were not measured when fans were reversed.

Temperature variation was symmetrical with distance from the reactor center. Thus, 80 thermocouples that were fastened to probes, were positioned in one half-section of the reactor as proposed by Smith and Eilers.⁹ Two probes with seven thermocouples each were placed in the center of the reactor (thermocouple depths of 15, 30, 80, 115, 135, 210 and 240 cm) and two probes with three thermocouples each (depths of

15, 135, and 240 cm) at 30-cm and 60-cm distances from the wall. A total of 20 thermocouples were placed in each section of the reactor. A temperature distribution over the entire cross-section of each reactor section was derived from 13 thermocouple readings by a surface-fitting technique based on spline interpolation.¹⁰ This distribution permitted the overall section mean temperatures and the fraction of the reactor volume that was within any given temperature range to be estimated.

To measure the CO₂ concentration in exhaust air, five 2-L beakers were buried upside down, 45-cm below the surface of the compost in each vessel and connected by a manifold, condensate flask, and dryer to an infrared CO₂ analyzer. Beakers were positioned equidistant across the width of the reactor to accommodate any variation in airflow through the compost in the vessels. Air was pulled under vacuum out of each vessel, dried and analyzed for CO₂ concentration. A reading was recorded only after a constant CO₂ value was achieved in the dry air moving through the analyzer. The CO₂ system was calibrated routinely by introducing 10% CO₂ from a standard pressurized cylinder into the manifold on the compost pile. The oxygen (O₂) concentration in exhaust air was measured manually with an O₂ electrode. Manual O₂ and CO₂ readings were also taken with a gas analyzer. The sum of O₂ and CO₂ values ranged from 18 to 21%.

Temperature, CO₂, and air flow data were automatically recorded every 4 hours on magnetic tapes which were later processed with a computer. The data were tabulated for each of the four reactor sections at each 4-hour time interval. These data included the following: temperature and relative humidity of the air entering the fans; temperatures at 13 locations within each section; means of 20 thermocouple readings in each section which were used to regulate fans; differential pressures measured in fan ducts; the length of time the fans were on during a 4-hour period; and the percent of CO₂ in the exhaust air. Air flow and the CO₂ weight produced for each section during each 4-hour interval were then calculated. The weights of dry air and CO₂ were determined using formulae derived from compost simulation models presented by Haug.¹¹

Sludge and bulking agents were mixed on an outdoor concrete pad with front-end loaders. In one trial a pugmill mixer was compared with mixing with front-end loaders. The reactor feed was then loaded into a live-bottom feed hopper and moved into the reactors by a continuous belt, tripper car, and indexing conveyor. Compost was turned or removed by an extractoveyor, loaded into trucks, weighed, returned to the reactor or stored in curing piles, or mixed into the reactor feed of the following trial as recycled compost. During the process of loading, turning, or removal of compost from the reactor, significant mixing occurred.

To obtain accurate materials balances, sludge and bulking agents (bark, sawdust, and recycled compost) were weighed separately using truck scales at the composting site. Samples for determination of percent dry and volatile solids (VS) of sludge and bulking agents were taken from each truck load. Additional samples were taken from reactor feed as it was loaded into the reactor.

Compost was turned typically 6 to 9 days after loading. During turning, compost was removed separately from each section by the extractoveyor, loaded into trucks, and reweighed. When this material was replaced in the appropriate section of the reactor, samples were taken again to determine dry solids

and VS. At the end of each trial the top 30–60 cm from each section was removed separately, weighed, and sampled for dry solids and VS and placed in curing piles. The dryer bottom portions were sampled and used as a bulking agent in subsequent trials.

Various bulking agents, including wood chips, hardwood tree barks, and sawdusts, were mixed with a mixture of waste activated and unstabilized primary sludge that had been dewatered with polymers. In preliminary trials, a 1:1 by volume mixture of sawdust and unprocessed hardwood tree bark (removed from trees by a variety of debarking systems) provided the best results. The bark particles ranged from dust-sizes to 3 cm by 3 cm by 25 cm pieces. Sawdust, hardwood tree bark, and recycled compost were used as the principal bulking agents.

The procedure used to determine free air space was a modification of a method used to determine "air-filled pore space levels" in container media used in horticulture.¹²

Percent of dry solids were determined at the composting site by drying samples to a constant weight in a forced-air oven (104°C). For determination of VS, all samples were ground to a fine powder in a mill before ashing (minimum of 1 hour at 550°C). Total Kjeldahl nitrogen (TKN), total organic carbon, carbon to nitrogen ratio, and pH of reactor feed and product were determined on three samples per reactor section. Conductivity in a saturated paste extract, pH, total nitrogen, phosphorus, and potassium, as well as concentrations of heavy metals were determined on cured compost of all seven trials. Further details on methods and procedures are presented in a project report to the U. S. Environmental Protection Agency (EPA).¹³

RESULTS

From October 1982 through March 1983, seven consecutive composting trials were performed. Mean percentages of dry solids and VS in these sludges were 21.6 and 58.9, respectively. A total of 731 metric tons of sludge (153.9 tons dry solids) were composted. The mean mixing ratios for sludge, sawdust, bark, and recycled compost in the trials were 1.0:0.3:0.4:2.8 by volume, respectively. Operating conditions of the trials varied; however, each trial was continued until the compost reached approximately 55% dry solids, resulting in losses of approximately 26% of the initial wet weight, 9.3% of initial dry solids and 40% of the initial water in the reactor feed. In winter trials, these losses were obtained with a compost retention time of 12.6 to 21.7 days. Full materials balances of each of the seven composting trials are presented elsewhere.¹³

Results for chemical analyses of the reactor product in all seven trials indicated that heavy metals were not concentrated with the bulking agent ratios used in these trials. The percent nitrogen (TKN) ranged from 1.7 to 2.0; the largest portion (1.3 to 1.8%) was organic nitrogen. There was neither an appreciable change in pH (7.0 to 7.5) nor an increase in conductivity (6.8–11 Mmhos/cm in the saturated paste extract) in the reactor products.

Temperature distribution. Temperature gradients associated with both depth and distance from the side walls were detected within hours after reactor feed was loaded in the reactor. Isotherms show that temperatures were highest near the center and top, and lowest near the bottom and sides of the reactor

(Figure 1). During periods of continuous aeration, temperatures in the bottom 30 cm were a few degrees lower than those of air entering at the fan. Gradients, therefore, reflect the evaporative cooling effect of air entering the reactor base.

During winter months, after compost was first loaded into the reactor and when air temperatures approached 0°C, the bottom layer of compost tended to freeze if the continuous aeration mode was used. This was avoided by using short bursts of air (1 minute out of 10) until temperatures in the reactor exceeded 35°C. Thereafter automatic temperature feedback was used to control the fans. However when air temperatures fell below -6°C intermittent aeration (1 to 2 minutes out of 30) was needed to avoid freezing.

Reversed airflow (negative instead of positive pressure aeration) resulted in an inverted gradient with wall effects similar to those under positive pressure aeration (Figure 2). With negative pressure aeration, water would accumulate in the lowest layer of compost when it was first loaded into the reactor, thus reducing airflow. This was not a problem toward the end of a trial when the compost had become dryer (50 to 60% dry solids).

Static head pressure and free air space. Static head pressures varied throughout the composting process. After compost was first loaded into the reactor, head pressures in the plenum under the reactor ranged from 12 to 18 cm (water). Pressures under the empty reactor vessel (before loading) ranged from 4 to 5 cm. During the first week, pressures usually decreased to 10 to 12 cm and then increased slightly as the compost mass settled in height from 2.9 m to approximately 2.4 m. After turning pressures were usually low (10 to 11 cm) and increased again as compost settled.

The percent of free air space also changed through the course of a given trial. Readings ranged from 33 to 45%. Increases in free air space caused by drying were largely offset by settling and, therefore, higher dry weight bulk densities of the compost. When sludge was mixed with bulking agents with a pugmill, significantly lower static head pressures were detected. Compost in pugmill-mixed sections dried much more rapidly than in the sections mixed with a front-end loader, which may have been caused by the absence of sludge balls in the pugmill-

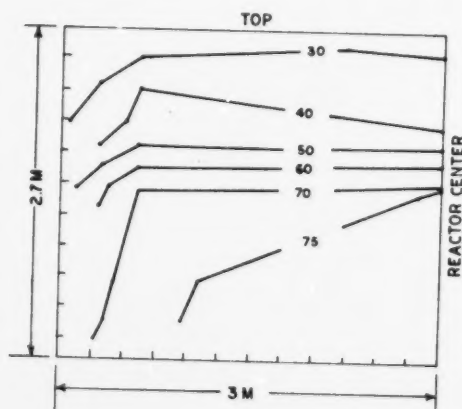


Figure 1—Typical temperature distribution obtained with positive pressure aeration, mean temperature = 54°C. Coordinates indicate depth and distance from side wall.

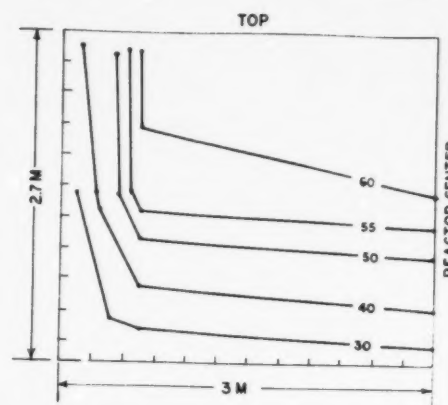


Figure 2—Typical temperature distribution obtained with negative pressure aeration, mean temperature = 65.9°C. Coordinates indicate depth and distance from side wall.

mixed reactor feed. After the first turn these differences were not detectable.

Aeration and carbon dioxide evolution. To evaluate effects of temperature on composting, reactor sections were kept at widely different temperatures by temperature feedback aeration. Relationships between aeration, temperature, and CO₂ evolution for sections at 42°C (designated as the cool section) and 70°C (hot section) are presented in Figures 3 and 4 for one such trial. In both sections mean temperatures were maintained at or very near the setpoints from Day 3 through 9. During this period, in the cool sections, 15 to 20% of the reactor volume was above 55°C and aeration rates were approximately 2500 kg dry air/h·section of compost. In the hot section, 75 to 80% of the reactor was above 55°C and aeration rates were only 500 kg dry air/h·section of compost. Aeration rates in the cool and hot sections equal approximately 23.3 and 4.6 kg dry air/h·m³ of compost respectively.

The amounts of CO₂ (kg/h) that evolved from cool sections were consistently higher than the amounts recorded from hot sections. Although CO₂ evolution tended to increase with

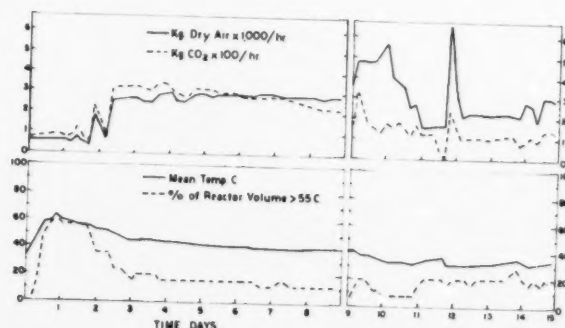


Figure 3—Aeration, CO₂ evolution and temperature data for the cool (43°C) section of Trial 2. Mean temperature and percent of reactor volume > 55°C are based on readings from 20 thermocouples. The compost was turned after 8.8 days and removed from the reactor 6 days later (Day 15).

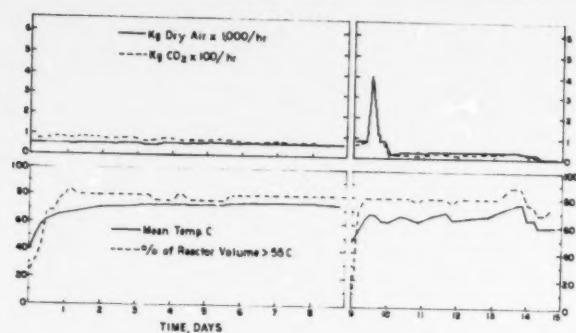


Figure 4—Aeration, CO₂ evolution and temperature data for the hot (65°C) section of Trial 2. Mean temperature and percent of reactor volume > 55°C are based on readings from 20 thermocouples. The compost was turned after 8.8 days and removed from the reactor 6 days later (Day 15).

increased aeration, there was a general decrease over time. For example, in the cool section (Figure 3) between Days 3 and 9, aeration increased gradually while CO₂ decreased steadily. In addition, amounts of CO₂ evolved during the last 4 days of composting were generally lower than those measured before turning.

The relationship between CO₂ evolution and mean compost temperature is illustrated in Figure 5. Although amounts of CO₂ evolved from the two sections after the turn (indicated by open symbols) were generally lower than those recorded before the turn (closed symbols), the amounts were highest in the section maintained at a mean temperature of 40 to 50°C.

The relationships between temperature, aeration, and CO₂

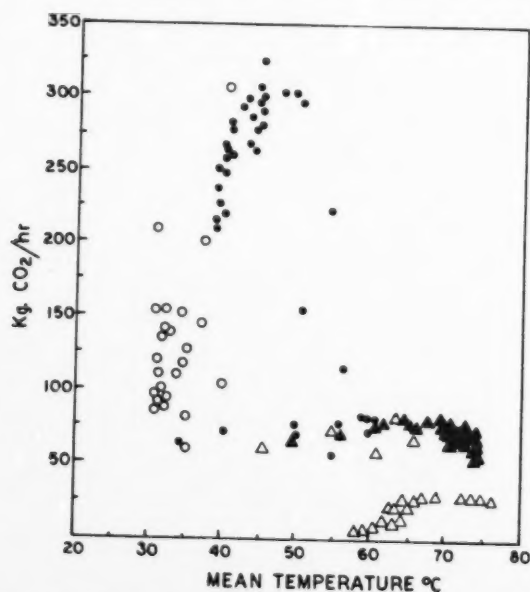


Figure 5—Relationship between CO₂ evolution and mean compost temperature. Readings taken every 4 hrs from cool section before turning, Days 1-9 (●); after turning, Days 9-15 (○); and from hot section before turning (▲) and after turning (△).

Table 1—Percent dry solids and percent loss of initial weight of dry solids for cool and hot sections of Trial 7.

	% dry solids		% Loss of initial weight dry solids	
	Cool	Hot	Cool	Hot
Reactor feed	48.2	48.3	—	—
Turn (5.6 days)	54.9	52.3 ^a	8.6	5.3
Reactor product (12.6 days)	60.8	55.4 ^b	14.8	10.0

^a Difference between cool and hot sections significant at $P = .05$.

^b Difference between cool and hot sections significant at $P = .01$.

evolution were confirmed in another trial (Trial 7) in which the compost was turned after 5.6 days and removed after 12.6 days. Differences between sections were statistically significant. More solids ($P = 0.05$) were destroyed in the cool than in the hot sections. Total weight loss of initial dry solids was nearly 15% in the cool, but only 10% in the hot sections (Table 1). Drying was also significantly better ($P = 0.01$) in the cool sections (Table 1).

Total weights of CO₂ and dry solids lost from the cool and hot sections before and after the turn in this trial are presented in Table 2. Theoretical CO₂ losses based on stoichiometric conversions of the destroyed solids are also presented in Table 2. Calculations were made for conversion of glucose to CO₂ and water, and also for sludge to CO₂, water, and NH₃. In general, actual measured CO₂ losses were closest to the values calculated for conversion of glucose.

CO₂ evolution rates (mg/g VS·h) in Table 3 for selected times represent high values recorded at the beginning of the trial and low rates measured before turning. For comparison with other studies, equivalent rates of oxygen consumption were calculated based on the assumption that glucose was metabolized.

Table 2—Measured and calculated losses of CO₂ (metric tons) from cool and hot sections of the reactor during Trial 7. Calculated values are based on losses of dry solids and stoichiometric formulae for oxidation of glucose and sludge.^a

Time period	Section	Measured CO ₂ lost	Calculated CO ₂ lost for:	
			sludge	glucose
Before turn	Cool	4.2	7.2	4.9
	Hot	2.5	4.4	3.0
After turn	Cool	5.6	5.3	3.5
	Hot	2.6	3.5	2.4
Total	Cool	9.8	12.5	8.4
	Hot	5.1	7.9	5.4

^a Stoichiometric formulae:

Sludge: $C_{10}H_{19}O_3H + 12.5 O_2 \rightarrow 10 CO_2 + 8H_2O + NH_3$

Glucose: $C_6H_{12}O_6 + 6 O_2 \rightarrow 6 CO_2 + 6H_2O$

Table 3—Carbon dioxide production and oxygen uptake determinations for cool and hot sections of Trial 7.

Section	Time (h from start of trial)	Mean temperature	Aeration rates $\text{m}^3/\text{ton VS} \cdot \text{h}$	$\text{Mg CO}_2/\text{g VS} \cdot \text{h}$	$\text{Mg O}_2/\text{g VS} \cdot \text{h}$
Cool	14	39.3	160		
	122	36.6	51	5.9	4.3
Hot	14	46.0		0.6	0.4
	122	54.5	30	2.6	1.9
			11	0.1	0.1

Note— O_2 calculated on the assumption that glucose is the primary carbon source.

DISCUSSION

Drying and VS destruction. Composting rates (drying and VS destruction) obtained during the seven consecutive winter trials were significantly greater than those published for the most widely used forced-aeration composting system in the U. S.—the Beltsville static aerated pile.¹ In that system approximately 30% of the initial wet weight and 10% of the dry solids typically are lost during a total of 42 days.¹⁴ By comparison, a mean of 25.7% wet weight and 9.3% dry solids were lost in a mean composting time of only 16 days in this study.

Most of the seven winter composting trials were designed to test the effects of aeration and temperature on the composting process. Often during these experiments unfavorable conditions for destruction of solids and drying were maintained in some sections of the vessels. In addition, all seven trials were performed during the coldest part of the year. Low air temperatures had a significant impact on aeration rates and the amount of time required for compost to reach the thermophilic temperature range. Therefore, data in this study do not represent optimal performance for this system. In fact, in an entire year study of the Paygro system a mean wet weight loss of 47.2% and a dry solids loss of 22.8% were achieved in 16.7 days of composting.¹⁵

Effects of aeration and process temperature. Drying and destruction of VS were highest with high aeration rates and low process temperatures. For example, during 12.6 days of composting, 14.8% of the initial dry solids were lost at a mean process temperature of 36 to 45°C, in contrast to a 10% loss at 46 to 68°C (Table 1). These results support the strategy of the Rutgers aerated static pile system, in which forced aeration and temperature feedback control was used to maintain low process temperatures.^{7,16} Rates of aeration used in the Rutgers system to achieve high drying rates with low process temperatures (25 $\text{m}^3/\text{h} \cdot \text{ton}$ initial wet weight) were roughly equal to those supplied to the cool sections in this study (22 $\text{m}^3/\text{h} \cdot \text{ton}$ initial wet weight).

It is difficult to quantitatively compare aeration rates used in this study to those in the Beltsville and Rutgers studies because comparable accurate measurements are not available for the aerated static pile studies. Likewise, CO_2 production cannot be compared quantitatively. In the Rutgers system, blower demand was cited as a measure of aeration requirement.¹⁶ However, this is not a quantitative measure of aeration. During each of the trials in the reactor the amount of time fans were on (blower demand) decreased with time. However, resistance to air flow (measured as fan head pressures) also decreased. Thus the amount of air forced through the reactor does not correspond directly to blower demand.

Rates of negative pressure aeration used routinely in the Beltsville system (14 $\text{m}^3/\text{h} \cdot \text{ton}$ sludge dry solids) are considerably lower than those used in this study (80 to 340 $\text{m}^3/\text{h} \cdot \text{ton}$ sludge dry solids). In the Beltsville system increases in negative pressure aeration rates (up to 36 $\text{m}^3/\text{h} \cdot \text{ton}$ sludge solids) increased drying. These aeration rates, however, were not sufficient to significantly reduce process temperatures below 60°C.¹⁷ Modifications in the Beltsville system that increased air flow through compost by reducing air leaks in the woodchip base, reducing moisture content of the initial mix, and using positive pressure aeration during the latter part of the composting period did reduce process temperatures and resulted in increased drying rates.¹⁸ These Beltsville studies, the Rutgers research,⁷ and this work all show that lower process temperatures, maintained through high aeration rates, effectively increase drying rates regardless of the configuration of the composting process. These results show for the first time that VS destruction, in addition to drying, is enhanced by low process temperatures in full-scale reactor systems.

Carbon dioxide evolution. This is the first full-scale composting study with municipal sludge for which quantitative measurements of CO_2 evolution and an accurate materials balance are available. The accuracy of the CO_2 monitoring system in this study is supported by comparisons of actual total amounts of CO_2 evolved during these trials and losses in VS based on stoichiometric conversion of VS to CO_2 (Table 2). Although, these CO_2 measurements do not consider the amount of CO_2 precipitated as carbonates in the compost, amounts of inorganic carbon did not increase significantly during the trials. Rates of CO_2 evolution and calculated rates of O_2 consumption for both high and low mean process temperatures (Table 3) fall well within the range of rates published for laboratory-scale studies of various sludge and refuse composts.³⁻⁶ Rates of CO_2 evolution recorded in the cool sections (5.9 $\text{mg/g VS} \cdot \text{h}$) were considerably higher than those cited in studies that replicated conditions of the Beltsville system (0.18 $\text{mg/g VS} \cdot \text{h}$). This difference is likely a result of differences in temperature and aeration but also caused at least in part by differences in the types of bulking agents used.

Bulking agents. Woodchips typically used in aerated static pile systems offer little available carbon substrate for the compost microorganisms, as compared with the sawdust and bark used in these studies. This is supported by the high NH_3 losses (deamination) reported for the Beltsville system.¹⁹ The rate-limiting factor in wood chips is the low ratio of surface area to total mass, thus providing a relatively small surface area for cellulase activity. In a preliminary trial with wood chips in the Paygro system, using bark and sawdust as controls,

high levels of ammonia were detected in the exhaust air over woodchip sections, an indication of deamination. This was not the case in trials with bark and sawdust. Unfortunately, quantitative measurements of NH_3 losses were not made in this study. Future research should examine the effects of bulking agent particle size on NH_3 evolution and microbial metabolism.

Hardwood tree bark and sawdust decompose much more rapidly than woodchips, if adequate nitrogen is supplied. Respiration rates during composting of nitrogen-amended bark may be as high as 0.9 to 1.00 mg/g VS $\cdot$ h O_2 .²⁰ Thus, the sludge in this study may have served as a source of nitrogen for decomposition of cellulose in sawdust and bark. In addition, stoichiometric conversion (Table 2) suggests that glucose, rather than sludge, was the principal source of carbon used by the compost microorganisms.

Microbial activity. Differences in loss of dry solids, changes in VS, and the amount of CO_2 evolved between cool and hot sections all support other studies that have reported high temperatures inhibit microbial activity. The relationship between mean compost temperature and CO_2 evolution shown in Figure 5 suggests that higher activity occurs when mean temperatures are below 60°C. However, significant portions of the vessel (approximately 20%) were above 60°C when mean temperatures were only 55°C (Figure 1). Therefore, the relationship between activity and mean temperature described for this system cannot be applied directly to laboratory-scale composting systems with much narrower temperature distributions. Nevertheless, data shown in Figure 5 agree closely with independent measures of microbial activity made by McKinley and Vestal,²¹ who reported that activity (as measured by ^{14}C -acetate uptake) per unit biomass was markedly reduced in sections where temperatures exceed 60°C. Some composting systems allow compost to be stacked 8 m deep. Aeration levels through the base of such vessels must be considerably higher than those reported for the Paygro and Rutgers systems to maintain temperatures suitable for high microbial activity.

Pathogen reduction. Although high levels of aeration result in low process temperatures, and therefore, high activity of the compost microorganisms (with increased drying and VS destruction), this approach to composting does not initially provide the high temperatures (>55°C) necessary to kill fecal pathogens. Federal regulations mandate that temperatures be maintained above 55°C for 3 continuous days. This research shows, however, that low process temperatures early in the composting cycle, when most of the volatile solids are destroyed (Table 3), can be followed by high process temperatures to meet the requirements. For example, airflow, when reversed from positive to negative, resulted in temperatures as high as 80°C throughout the reactor base (Figure 2).

Regardless of the operational mode, a curing phase is desirable for all composting systems for many reasons. Temperatures in curing piles reached 70°C for up to 1 week within several days after removal from the reactor. Thereafter, temperatures gradually decreased to below 55°C. Fecal pathogen kill can, therefore, be easily accomplished during curing.

To minimize construction costs related to reactor size, operating costs, and potential odor problems, composting plants should be maintained as near to optimum process temperatures as possible. The fate of fecal pathogens should be determined in the least cost-intensive phase of composting, that is, the curing pile.

CONCLUSIONS

Rates of drying and VS destruction were higher than those reported for the Beltsville static aerated pile. The highest composting rates were achieved when mean compost temperatures were maintained below 60°C by high airflow rates. Rates of CO_2 evolution measured in the full-scale reactor vessels were comparable to those reported in various laboratory-scale studies, and indicated that microbial activity was greatest when mean compost temperatures were 40 to 60°C.

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